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Dietary Amino Acid and Sodium Bicarbonate Responses in Broilers Reared in Hot Environmental Temperatures[1,2]

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Primary Audience: Nutritionists, Researchers, Feed Manufacturers

SUMMARY

Better environmentally controlled broiler houses have resulted in many integrated broiler operations using the same dietary feed formulations in winter and summer months due to only minor differences in environmental temperature in the broiler house. Much research has addressed broiler nutrient needs in thermoneutral vs. hot temperature conditions, but research evaluating nutrient needs of broilers during moderate temperature conditions (tunnel-ventilated houses during summer months) is lacking. This study evaluates the impact of increasing dietary Lys and other essential amino acids, and the addition of dietary sodium bicarbonate in high and moderate temperature conditions. Experiment 1 was conducted in batteries and evaluated broiler nutritional responses (d 20 to 40) in hot-cyclic temperature conditions (26 to 34°C). Experiment 2 was conducted in floor pens and evaluated broiler nutritional responses (d 37 to 49) in environmental temperature ranges that mimic a tunnel-ventilated broiler house during summer months (26 to 31°C). In both experiments, dietary treatments had minimal impact on live performance and breast meat yield. Lower mortality ($P < 0.06$), however, was observed in broilers fed the low CP diet in the hot temperature environment.

Key words: broiler, environmental temperature, lysine, amino acid, breast yield

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DESCRIPTION OF PROBLEM

Much progress has been made in the design of poultry houses in recent years. The majority of poultry houses in the U.S. today are tunnel-ventilated. These tunnel-ventilated houses have increased air movement (negative pressure), resulting in the ability to cool broilers in summer months better than that of broiler houses ventilated by means other than tunnel

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ventilation. As a result, many broiler companies that have the majority of their broilers reared in tunnel-ventilated houses use only one feed formulation regime rather than separate regimes for summer and winter flocks.

Calculating amino acid needs for broilers reared in environmental temperatures above their thermoneutral zone remains problematic. A research study by Waldroup [1] was conducted in male and female broilers during the summer months to determine the extent to which CP could be reduced while supporting good growth. Low CP diets formulated to contain supplemental sources of methionine and lysine resulted in optimal growth [1]. Reducing dietary CP and minimizing amino acid excesses for birds reared in hot temperatures is supported by additional research [2, 3]. Lowering dietary CP, however, results in a reduction in potassium because its main contributing source (i.e., soybean meal) is reduced in the diet. The scenario poses an additional problem for nutritionists formulating diets for broilers in hot temperatures because mineral nutrition (e.g., mainly electrolytes) is of importance [4] in broilers reared in temperatures outside their thermoneutral zone. For example, Balnave and Gorman [5] have shown the benefits of fortifying diets with sodium bicarbonate in broilers reared in high environmental temperatures.

It is generally assumed that dietary CP should be reduced in broilers reared in hot temperatures. Research studies, however, differ from this in that some have shown benefits by reducing CP and minimizing amino acids [1, 2, 3], whereas others have shown no correlation between CP and environmental temperature [6, 7]. Morevoer, research has shown benefits in broiler performance in temperatures above their thermoneutral zone as dietary Arg is increased relative to Lys [8]. Practically, increasing the Arg:Lys ratio in broiler diets is costly because it usually is accomplished by increasing soybean meal as crystalline L-Arg is not commercially available. However, increasing the Arg:Lys ratio in broilers reared in hot temperature conditions has been shown to decrease breast meat yield [9]. A deficient dietary Lys level will decrease breast meat yield in broilers [10], but a marginal deficiency of Lys in broilers reared in hot temperatures has been shown to improve performance [7]. Hence, practical amino acid recommendations for broilers reared in hot temperature conditions remains unclear.

The main objective of this study was to evaluate the impact of dietary lysine on growth and carcass attributes of growing and finishing broilers reared in hot temperatures. Experiment 1 was conducted to evaluate the impact of increasing Lys and other essential amino acids and sodium bicarbonate in growing male broilers reared in hot temperature conditions. Because most research studies evaluating amino acid needs for heat-stressed broilers have been conducted in environmental temperatures that do not mimic temperatures of broilers being reared in tunnel-ventilated houses during the summer months, experiment 2 was conducted to evaluate CP, Lys, and sodium bicarbonate responses in finishing broilers reared in floor pens in moderately high temperatures.

MATERIALS AND METHODS

Experiment 1

Dietary treatments were tested from d 20 to 40. Cobb 500 male broilers were obtained from a commercial hatchery at d 1 after receiving vaccinations (Marek's disease, Newcastle disease, and infectious bronchitis). Chicks were randomly placed (eight birds/pen) in a 24-cage battery unit and fed a common mash diet that met or exceeded nutrient recommendations [11] for the 1- to 20-d period. At d 20, 150 broilers were randomly allocated to 30 finishing battery pens (five birds/pen).

One large batch of the control test diet (Table 1) fed from d 20 to 40 was mixed in a vertical mixer. Random aliquots of the control diet were obtained and dietary treatments were achieved by adding the test ingredients during remixing in a horizontal mixer. Mash treatments consisted of: 1) the control diet; 2) as 1 plus dietary L-Lys HCl added to 107% of the NRC [11] Lys specification; 3) as 2 plus L-Thr added to 100% of the Thr recommendation [11] level; 4) as 2 plus L-arginine to obtain a total Arg:Lys ratio of 1.35; and 5) as 2 plus dietary sodium bicarbonate to obtain an electrolyte balance of 225 mEq/kg of diet (six replications/treatment). All dietary treatments were

TABLE 1. Composition (%) of experimental diets fed from 20 to 40 d of age (experiment 1)

	Treatments[a]				
Ingredients	Control	Lysine	Lysine and threonine	Lysine and arginine	Lysine and $NaHCO_3$
Corn	63.92	63.92	63.92	63.92	63.92
Soybean meal, 48% CP	27.52	27.52	27.52	27.52	27.52
Poultry fat	4.30	4.30	4.30	4.30	4.30
Dicalcium P	1.67	1.67	1.67	1.67	1.67
Limestone	1.17	1.17	1.17	1.17	1.17
Filler[B]	0.52	0.40	0.35	0.16	0.06
NaCl	0.33	0.33	0.33	0.33	0.33
Premix[C]	0.25	0.25	0.25	0.25	0.25
DL-Met	0.22	0.22	0.22	0.22	0.22
Coban	0.08	0.08	0.08	0.08	0.08
L-Lys HCl	0.03	0.12	0.12	0.12	0.12
L-Thr	0.00	0.00	0.05	0.00	0.00
L-Arg	0.00	0.00	0.00	0.24	0.00
$NaHCO_3$	0.00	0.00	0.00	0.00	0.34
Calculated composition					
ME, kcal/kg	3,200	3,200	3,200	3,200	3,200
CP, %	18.78	18.78	18.78	18.78	18.78
TSAA, %	0.83	0.83	0.83	0.83	0.83
Lys, %	1.00	1.07	1.07	1.07	1.07
Thr, %	0.70	0.70	0.75	0.70	0.70
Arg, %	1.20	1.20	1.20	1.44	1.20
Ile, %	0.77	0.77	0.77	0.77	0.77
Val, %	0.87	0.87	0.87	0.87	0.87
Trp, %	0.24	0.24	0.24	0.24	0.24
DEB, mEq/kg[A]	187	187	187	187	225
Na, %	0.15	0.15	0.15	0.15	0.24
Ca, %	0.90	0.90	0.90	0.90	0.90
P, nonphytate, %	0.42	0.42	0.42	0.42	0.42
Analyzed composition					
CP, %	18.02	18.57	19.13	18.91	19.50
Lys, %	0.87	0.92	1.06	0.97	0.99
Thr, %	0.70	0.71	0.77	0.74	0.76
Arg, %	1.16	1.22	1.21	1.49	1.31

[A]Treatments represented: control; lysine, the control diet supplemented with L-Lys HCl to 107% of the recommended level [11]; lysine and threonine, L-Thr was added to the high Lys diet to achieve a total Thr/Lys of 0.70; lysine and arginine, L-Arg was added to the high Lys diet to achieve a total Arg/Lys of 1.35; lysine and sodium bicarbonate, $NaHCO_3$ was added to the high Lys diet to achieve a total DEB (dietary electrolyte balance; Na+K-Cl) of 225 and a total Na level of 0.24.
[B]Treatments were added to the control diet in place of the filler (sand).
[C]Premix provided the following per kilogram of diet: vitamin A (vitamin A acetate) 7,716 IU; cholecalciferol 2,205 IU; vitamin E (source unspecified), 9.9 IU; menadione, 0.9 mg; B_{12}, 11μg; choline, 379 mg; riboflavin, 5.0 mg; niacin, 33 mg; D-biotin, 0.05 mg; pyridoxine, 0.9 mg; D-pantothenic acid, 9 mg; thiamine, 1.0 mg; ethoxyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 4 mg; iodine, 1 mg; selenium, 0.1 mg.

obtained by adding the test ingredient in place of the filler.

Birds were provided 23 h of light and 1 h of dark. Temperature was controlled in the experimental facility and cycled for 12 h at an average temperature of 34°C followed by 12 h at an average temperature of 26°C for the 20- to 40-d period. Feed and water were provided ad libitum in troughs. Body weight by pen was measured at d 20 and 40. Feed consumption, mortality, and the weight of mortality were recorded throughout the 20- to 40-d period. Feed conversion represents the weight of feed consumed divided by the BW gain for the 20- to 40-d, period and corrected feed conversion uses the weight of mortality to adjust feed consumption. At d 40, all birds were processed and carcass weight and abdominal fat were weighed. In addition, the *Pectoralis major* and *Pectoralis minor* breast muscles were

TABLE 2. Composition (%) of experimental diets fed from 37 to 49 d of age (experiment 2)

	Treatments[A]			
Ingredients	High protein	Low protein	Low protein and lysine	Low protein, lysine and $NaHCO_3$
Corn	69.88	74.24	74.24	74.20
Soybean meal, 48% CP	24.27	19.98	19.98	19.99
Poultry fat	2.69	2.23	2.23	2.24
Defluorinated P	1.34	1.37	1.37	1.37
Limestone	0.77	0.77	0.77	0.77
NaCl	0.40	0.39	0.39	0.36
DL-Met	0.26	0.31	0.31	0.31
Vit/min premix[B]	0.25	0.25	0.25	0.25
Filler[C]	0.15	0.15	0.08	0.08
L-Lys SO_4	0.00	0.24	0.31	0.31
L-Thr	0.00	0.07	0.07	0.07
$NaHCO_3$	0.00	0.00	0.00	0.05
Calculated composition				
ME, kcal/kg	3,174	3,174	3,174	3,174
CP, %	17.71	16.00	16.00	16.00
TSAA, %	0.85	0.85	0.85	0.85
Lys, %	0.90	0.90	0.97	0.97
Thr, %	0.66	0.66	0.66	0.66
Ile, %	0.72	0.64	0.64	0.64
Arg, %	1.11	0.98	0.98	0.98
Val, %	0.82	0.74	0.74	0.74
Trp, %	0.22	0.19	0.19	0.19
Na, %	0.24	0.24	0.24	0.24
Cl, %	0.28	0.28	0.28	0.26
K, %	0.69	0.62	0.62	0.62
DEB, mEq/kg	204	187	187	192
Ca, %	0.80	0.80	0.80	0.80
P, nonphytate, %	0.35	0.35	0.35	0.35
Analyzed composition				
CP, %	17.52	15.84	16.37	16.08
Lys, %	0.92	0.90	1.03	1.03

[A]Treatments represented: 1) the high CP diet; 2) the low CP diet; 3) as 2 with increased Lys as achieved by adding L-Lys SO_4 in place of the filler; and 4) as 3 with a minimum ingredient constraint in least-cost formulation of 0.05% sodium bicarbonate.
[B]Premix provided the following per kilogram of diet: vitamin A (vitamin A acetate) 7,716 IU; cholecalciferol 2,205 IU; vitamin E (source unspecified) 9.9 IU; menadione, 0.9 mg; B_{12}, 11 μg; choline, 379 mg; riboflavin, 5.0 mg; niacin, 33 mg; D-biotin, 0.05 mg; pyridoxine, 0.9 mg; D-pantothenic acid, 9 mg; thiamine, 1.0 mg; ethoxyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 4 mg; iodine, 1 mg; selenium, 0.1 mg.
[C]Treatments were added to the control diet in place of the filler (sand).

cone deboned after chilling. Live performance and carcass measurements were analyzed [12] by pen.

Experiment 2

This experiment was conducted to evaluate dietary CP, lysine, and sodium bicarbonate responses during the 37- to 49-d period. Twelve hundred 1-d-old Ross × Ross 308 male broilers were obtained from a commercial hatchery and randomly allocated to floor pens. All birds received a Marek's vaccination in ovo. Broilers were used for an amino acid research trial from d 1 to 18. However, broilers were fed a common mash grower diet from d 19 to 36 that met or exceeded recommended nutrient levels [11]. Each floor pen (30 broiler/pen) contained one bell drinker, one tube feeder, and built up pine shavings. On d 37, broilers (1,100) were mixed, randomly caught, placed in coops, and transferred to the experimental facility. Broilers were randomly allocated to floor pens (1.5 × 3.6 m, 55 birds/pen) containing one trough waterer (2.3 m in length), two tube feeders,

TABLE 3. Live performance measurements of male broilers as affected by dietary treatments for the 20- to 40-d period (experiment 1)

Treatments[A]	BW gain	Feed conversion	Corrected feed conversion	Mortality
	(g/bird per d)	(g/g)	(g/g)	(%)
Control	56.5	2.23	1.96	10.0
Control + Lys	58.7	2.68	1.98	16.7
Control + Lys + Thr	53.8	1.98	1.95	3.3
Control + Lys + Arg	59.6	2.01	1.87	6.7
Control + Lys + $NaHCO_3$	58.5	1.86	1.86	0.0
SEM	2.3	0.23	0.05	4.8
Probability	0.423	0.117	0.388	0.158

[A]Treatments represent: 1) Control = the control test diet; 2) Control + Lys = as 1 plus dietary L-Lys HCl added to meet to 107% of the NRC [11] Lys specification; 3) Control + Lys + Thr = as 2 plus L-Thr added to meet 100% of the Thr recommendation [11] level; 4) Control + Lys + Arg = as 2 plus L-arginine to obtain a total Arg:Lys ratio of 1.35; and 5) Control + Lys + $NaHCO_3$ = as 2 plus dietary sodium bicarbonate to obtain an electrolyte balance of 225 mEq/kg of diet.

and new pine shavings. Birds had ad libitum access to feed and water. The lighting program consisted of 24 hr of light.

Dietary treatments (Table 2) were mixed in a horizontal mixer and steam pelleted. All treatments were mixed individually in a horizontal mixer prior to pelleting. Dietary treatments were replicated four times and consisted of: 1) the high CP (17.7% CP) diet; 2) the low CP diet (16.0% CP); 3) as 2 with increased Lys as achieved by adding L-Lys SO_4 in place of the filler; and 4) as 3 with a minimum ingredient constraint in least-cost formulation of 0.05% sodium bicarbonate. Average daily low and high temperatures in the experimental facility were 26.2°C and 30.5°C, respectively. The temperature cycled so that the high temperatures were maintained for 9 hr and the low temperatures were maintained for 15 hr. Live performance and carcass measurements identical to experiment 1 were obtained for the 37- to 49-d period and analyzed [12].

RESULTS AND DISCUSSION

Diets formulated to minimize CP, and thus essential amino acid excesses, have been shown to improve the growth of broilers reared in hot temperature conditions [1]. Although feed intake is depressed in broilers reared in hot temperatures, fortifying diets with high levels of essential amino acids as a means to compensate for the reduced feed intake has been shown to result in deleterious effects on broiler growth responses [3]. However, research reports do not agree on how to formulate

TABLE 4. Processing measurements of male broilers as affected by dietary treatments for the 20- to 40-d period (experiment 1)

			Carcass		Breast	
Treatments[A]	Processing BW[B] (kg)	Abdominal fat (%)	Weight, kg	Yield, %	Weight (kg)	Yield[C] (%)
Control	1.850	1.03	1.238	66.89	0.296	16.01
Control + Lys	1.877	0.90	1.276	68.08	0.325	17.32
Control + Lys + Thr	1.818	0.83	1.194	65.70	0.302	16.61
Control + Lys + Arg	1.918	0.90	1.267	66.06	0.316	16.46
Control + Lys + $NaHCO_3$	1.918	1.03	1.258	65.64	0.320	16.68
SEM	0.039	0.08	0.029	1.15	0.008	0.30
Probability	0.308	0.290	0.307	0.533	0.130	0.078

[A]Treatments represent: 1) Control = the control test diet; 2) Control + Lys = as 1 plus dietary L-Lys HCl added to meet to 107% of the NRC [11] Lys specification; 3) Control + Lys + Thr = as 2 plus L-Thr added to meet 100% of the Thr recommendation [11] level; 4) Control + Lys + Arg = as 2 plus L-arginine to obtain a total Arg:Lys ratio of 1.35; and 5) Control + Lys + $NaHCO_3$ = as 2 plus dietary sodium bicarbonate to obtain an electrolyte balance of 225 mEq/kg of diet.
[B]BW of broilers at processing.
[C]Breast yield relative to processing BW.

TABLE 5. Live performance measurements of male broilers as affected by dietary treatments for the 37- to 49-d period (experiment 2)

Treatments[A]	BW gain (g/bird per d)	Feed conversion (g/g)	Corrected feed conversion (g/g)	Mortality (%)
High CP	75.7	2.71	2.57	5.0
Low CP	82.4	2.48	2.48	0.0
Low CP + Lys	84.1	2.51	2.40	4.5
Low CP + Lys + $NaHCO_3$	69.6	2.96	2.83	4.1
SEM	5.2	0.15	0.12	1.16
Probability	0.230	0.140	0.100	0.055

[A]Treatments represent: 1) High CP = birds fed the high (17.7% CP) CP diet; 2) Low CP = birds fed the low CP diet (16.0% CP); 3) Low CP + Lys = birds fed the low CP diet supplemented with lysine to 0.97% total lysine; and 4) Low CP + Lys + $NaHCO_3$ = birds fed the low CP diet supplemented with lysine and sodium bicarbonate to 0.97% total lysine and a dietary electrolyte balance of 192 mEq/kg. The average high and low temperatures for the 11- d period were 30.5 and 26.2°C, respectively.

dietary CP for broilers reared in hot temperature conditions. Because it is economically advantageous to formulate diets minimizing CP, this study was conducted to evaluate the impact of supplemental Lys, other essential amino acids, and sodium bicarbonate to low CP diets fed to growing and finishing broilers.

Live performance measurements in experiment 1 did not significantly differ between treatments (Table 3). Similarly, significant differences in carcass measurements did not occur in experiment 1 (Table 4). However, birds receiving increased Lys had higher ($P = 0.078$) breast meat yield than birds fed the low Lys (control) diet. The dietary addition of Thr, Arg, and sodium bicarbonate to the high Lys diet had no effect on breast meat yield. Treatment differences ($P < 0.05$) did not occur for growth measurements in experiment 2 (Table 5). However, birds fed the low CP diet without additional Lys and sodium bicarbonate had no mortality, which was better ($P = 0.055$) than the other treatments. An additional group of Ross 308 males (four pens of 55 birds each) received the high CP diet from d 37 to 49 and were reared at average high and low temperatures of 21.8 and 17.0°C, respectively. These birds reared at the cool temperatures had an average daily gain of 93 g/bird per day (data not presented) vs. an average daily gain of all treatments reared in the hot environment of 78 g/bird per day (Table 5). Although growth responses did not differ, the low CP diet may have resulted in lower mortality

TABLE 6. Processing measurements of male broilers as affected by dietary treatments for the 37- to 49-d period (experiment 2)

Treatments[A]	Processing BW[B] (kg)	Abdominal fat, %	Carcass Weight (kg)	Carcass Yield (%)	Breast Weight (kg)	Breast Yield[C] (%)
High CP	2.748	1.54	1.944	70.75	0.502	18.28
Low CP	2.689	1.70	1.894	70.52	0.486	18.08
Low CP + Lys	2.750	1.66	1.943	70.65	0.489	17.80
Low CP + Lys + $NaHCO_3$	2.730	1.71	1.920	70.32	0.489	17.91
SEM	0.031	0.05	0.020	0.38	0.009	0.18
Probability	0.486	0.154	0.313	0.864	0.595	0.319

[A]Treatments represent: 1) High CP = birds fed the high (17.7% CP) CP diet; 2) Low CP = birds fed the low CP diet (16.0% CP); 3) Low CP + Lys = birds fed the low CP diet supplemented with lysine to 0.97% total lysine; and 4) Low CP + Lys + $NaHCO_3$ = birds fed the low CP diet supplemented with lysine and sodium bicarbonate to 0.97% total lysine and a dietary electrolyte balance of 192 mEq/kg.M The average high and low temperatures for the 11-d period were 30.5 and 26.2°C, respectively.
[B]BW of broilers at processing.
[C]Breast yield relative to processing BW.

due to a reduced heat increment. Carcass characteristics were unaffected by dietary treatments in experiment 2 (Table 6).

Results of experiment 1 indicate that the control diet was not limiting in essential amino acids. Results of experiment 2, however, indicate that increasing dietary Lys to birds reared in hot temperature conditions had no beneficial effect. Research has indicated that the dietary Lys requirement is not affected by temperature [7]. New Hampshire x Columbian crossbred female (but not male) birds had an increased dietary requirement for Lys when reared in hot temperature conditions [14]. Male Cobb and Ross broilers were used in experiments 1 and 2, respectively. It has been shown that broilers from different genetic lines differing in growth characteristics respond differently in terms of fat and protein accretion when reared in hot temperature environments [15]. The dietary addition of sodium bicarbonate did not improve any parameter measured in either experiment.

CONCLUSIONS AND APPLICATIONS

1. Increasing dietary Lys in experiment 1 from 100 to 107% of the 1994 NRC in 20- to 40-d-old Cobb 500 male broilers reared in hot temperatures (average high of 34°C and average low of 26°C) failed to increase live performance and breast meat yield.
2. Increasing Lys (0.90 to 0.97% of diet) in experiment 2 to the low CP diet failed to improve live performance or carcass traits of finishing (d 37 to 49) Ross 308 male broilers, but broilers had lower mortality when fed the low CP diet without additional Lys (0.90% total Lys) and sodium bicarbonate.

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